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Preparation and Characterization of Polypropylene/Heart-of-Peach Palm Sheath Composite

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ABSTRACT: This article presents preparation of heart-of-peach palm sheath (20–40 wt %) incorporated polypropylene (PP) composites using a single screw extruder. This study is aimed at the waste disposal problem, a societal concern considering that the peach palm cultivation being an important economic activity of some countries, which generate five times more waste than actual heart-of-palm itself. Both the raw materials and their composites were characterized for specific gravity, compressive and impact strengths, softening temperature, and hardness. It was observed that with increasing filler content the compressive and impact strengths of composites continuously decreased, while specific gravity, vicat softening temperature, and hardness showed the opposite trend. However, the optimum mechanical properties were attained for 30 wt % filler, which was the same filler content at which the highest PP crystallinity index was observed. Results also indicate that the lignocellulosic residue induce beta phase on the PP matrix and decrease thermal stability of the composite. © 2012 Wiley Periodicals, Inc. J. Appl. Polym. Sci. 000: 000–000, 2012

KEYWORDS: polymer–matrix composite; thermal properties; mechanical properties; X-ray diffraction; extrusion

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INTRODUCTION

It is well established that polymer-based composites with lignocellulosic fibers from plants such as bagasse, coir, cotton, curaua, flax, jute, kenaf, sisal, or powder from palm trees and even wood as a fillers or reinforcements are finding uses in the production of a variety of goods, such as automotive parts, frames, decks, sidings, etc.[1–10] Even attempts have been made to use palm oil shell as coarse aggregate in lightweight concrete[11] as energy source, while its ash is used for blending with cement.[12] One of the reasons for the lignocellulosic materials to become popular as fillers or reinforcements in polymer or ceramic matrices is due to their advantages over other inorganic or synthetic materials. These include that they are renewable, widely distributed all over the world, recyclable, versatile, nonabrasive, easily available, biodegradable, reactive, and not expensive.

Among the polymers, polypropylene (PP), being a commodity polymer, has been used in a wide range of automotive and packaging applications. This is mainly due to its possessing many desirable properties such as low density, high thermal stability, and good solvent resistance, despite its low elastic modulus compared with other engineering polymers such as polycarbonate. It is also known that among various phases of PP, β-type shows better properties,[2,3,13–18] and hence many a times, β nucleating agents such as calcium carbonate or aryl amide are used. In addition, researchers have overcome the limitation of PP through the addition of many fillers (micro or nano), whereby it has been possible to improve not only the mechanical properties but also thermal properties of PP.[2,3,18] However, some of the characteristics of such fillers need to be considered are their size and aspect ratios that limits the amount of these fillers to be incorporated to significantly enhance the properties. Amount of fillers to be incorporated dictates not only the processability but also ductility, impact strength, and surface finish, while type of filler affects the crystallization behavior and nucleation of β-phase.[17] Accordingly, in this study heart-of-peach palm sheath was chosen as filler.

Palm trees have an important economic role in Latin America and many countries in Asia.[19] Among various palm trees, peach palm trees (*Bactris gasipaes*) shown in Figure 1(a) are cultivated

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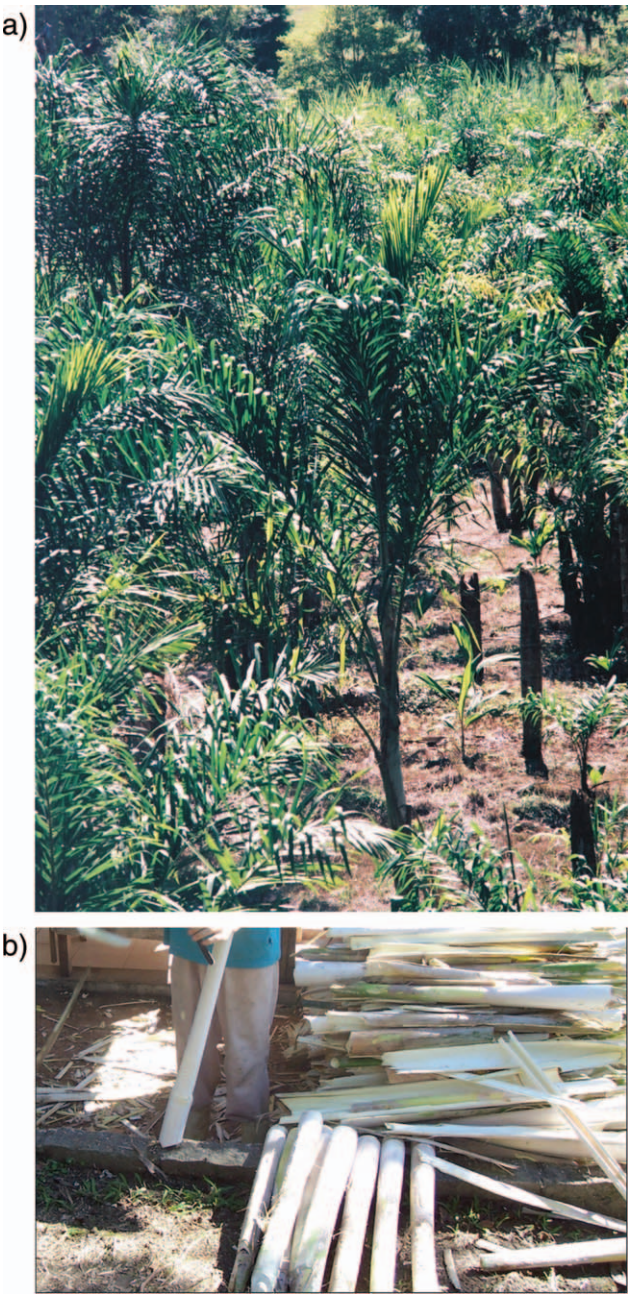

Figure 1. (a) Heart-of-peach palm (*Bactris gasipaes*) (b) heart-of-peach palm being prepared. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

in Central America and Brazil and the heart-of-palm is extracted as shown in Figure 1(b), which is either undeveloped but growing inner core or the embryonic shoot that occurs at the tip of the stem.

These plantations have been introduced in south and southeast regions of Brazil to avoid exploitation of *palmito* (heart-of-palm) from the native *juçara* palm (*Euterpe edulis*), an endangered species in the Mata Atlântica rain forest. This has led to an increased number in small industries processing the heart-of-palm from peach palm in these regions. Heart-of-palm from *juçara* palm is often eaten in salads or other recipes and it is economically and environmentally costly because of harvesting them from the stem of the tree, and accordingly, it has become necessary to destroy the palm particularly inside Mata Atlantica rain forest, resulting in the species being under extinction.

While various palm-based materials, such as stems, leaves, fruits, and seeds, have been used to prepare polymer-based composites,[20–23] only powder or small chips from stems[24,25] and fibers from leaves[25] have been used in the case of heart-of-peach palm. As just one-fifth of the inner part of the stem tip can be used as human food, in the latter case, there remains a huge amount of peach palm, particularly, the sheath becoming waste. Considering the above two points in the case of heart-of-peach palm, any attempt to increase the use of this waste material will lead to value addition for this material. In this direction, incorporation of heart-of-palm sheath waste into any polymer matrix will be a strategic path to explore alternatives with value addition to the economic chain of peach palm.

Therefore, the aim of this work is at the preparation and characterization of composites of "heart-of-peach palm sheath residue waste" (hereafter referred to as "waste residue") with PP, which is a partly biodegradable polymer, with a view to find an environmentally friendly destination for peach crop residues.

EXPERIMENTAL

Materials

Heart-of-peach palm sheath was collected from a small industry in Santa Catarina State, Southern Brazil, that processes heart-of-palm. This material, which showed humidity of ~ 70% on wet weight base, was oven dried at 65–70°C for 72 h and then cut into small lengths on a Wiley mill.

The polyolefin used was the PP H103 having a density of 0.905 g/cm^3 and melt flow rate of 40 g/10 min supplied by Braskem (Brazil). Its number average molecular weight (M_n) is 49,440 and the weight average molecular weight (M_w) is 235,597, while its molecular weight distribution is shown in Figure 2 as supplied by the manufacturers and suppliers.

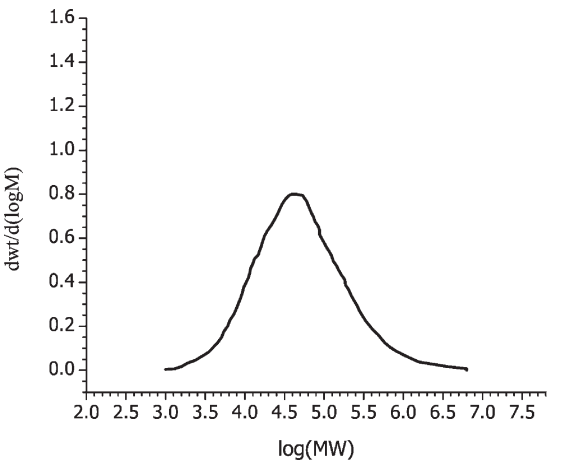

Figure 2. Molecular weight distribution of PP supplied by the manufacturers and suppliers.

Methods

Preparation of Composites. The chipped heart-of-peach palm sheath waste was hand-mixed in a bowl with PP pellets before compounding through a single screw extruder (Ciola, model B-50, screw diameter of 50 mm).

Although the moisture content of the filler was somewhat high for thermoplastic composites, the heart-of-peach sheath waste residue was successfully incorporated with weight ratios of 20 : 80, 30 : 70, and 40 : 60 of heart-of-peach palm sheath/PP with 40% of waste residue being the maximum (It may be noted hereafter unless otherwise mentioned the above ratios refer to 20, 30, and 40 wt %, respectively, of the waste residue and mentioned as 20, 30 and 40 % waste residue, respectively). No additives were used. Along the 1.25-m long screw, the temperature was set at 165°C in the feed region and 185°C in the composite exit. The mixed composites were granulated and then moulded using an injection moulding machine (Sandretto, Mic O65 model). The composite specimens were moulded into ISO standard specimens, which were then subjected to various characterizations.

Specific Gravity. Specific gravity of both the matrix PP and its composites was determined as per ASTM D792–08 standard test methods for density and specific gravity (relative density) of plastics by displacement method.

Chemical Composition of Heart Peach Palm Sheath. Chemical properties of heart peach palm sheath (total extractives, Klason lignin, and ash content) were evaluated through wet chemistry as reported earlier[26] using Brazilian standards NBR 14853, 7989, and 13999 (ABNT–Associação Brasileira De Normas E Técnicas). In brief, first, solvent extraction with toluene, ethanol, and dichloromethane was carried out using Soxhlet apparatus, and then Klason lignin was evaluated as sulfuric acid insoluble material. Finally, ash content was determined by heating samples in a muffle furnace at 525°C.

Cellulose and hemicelluloses were evaluated using a methodology described elsewhere.[27] First, solvent extraction was performed in a Soxhlet apparatus with a 2 : 1 mixture of toluene/ethanol for 6 h. Second, lignin in the sample was removed using an acidified sodium chlorite solution at 70°C for 1 h, and the process was repeated until the product became white. Third, the sample was treated overnight in 6 wt % potassium hydroxide at room temperature and then at the same concentration at 80°C for 2 h, to leach out hemicelluloses.

X-ray Diffraction Studies. X-ray diffraction studies were carried out for the matrix PP and the composites using a wide angle X-ray diffractometer (WAXD) on a Shimadzu XRD 6000 instrument. A conventional CuKα X-ray tube at a voltage of 40 kV and a filament current of 30 mA was used to obtain the WAXD diffractograms. The scanning 2θ range was from 5° to 45° with a scanning rate of 1° per min.

Thermal Studies. With a view to evaluate the thermal parameters, such as crystallization temperature [T_c], melting temperature [T_m], heat of fusion [ΔH_f], and percentage of crystallinity [X_c] through thermograms, the differential scanning calorimetry (DSC) technique was used. For this purpose, a Shimadzu 60H instrument was used with a temperature range of each scan of 25–500°C at a fixed heating rate of 10°C/min. Two methods were followed. In the first case, for crystallization temperature experiments, the samples were heated to 180°C and maintained at this temperature for 5 min. The samples were then cooled to 28°C at a rate of 5°C/min. On the other hand, for determining both the melting temperatures, the samples were heated till 600° C, leading to the composite degradation. The purpose of the latter is to understand the behavior of composites compared with neat PP in terms of thermal degradation.

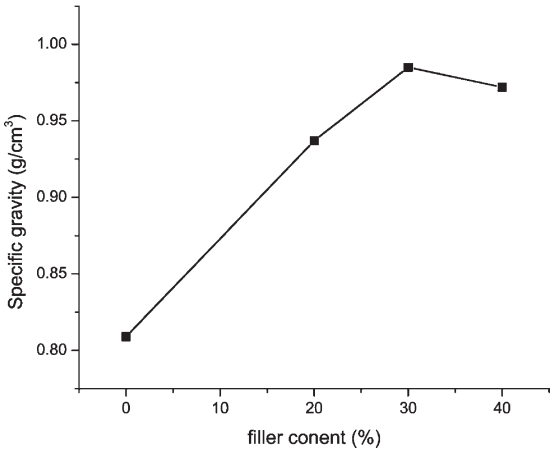

Figure 3. Variation of specific gravity of PP–heart-of-peach palm sheath composite with the latter's content.

Mechanical Property Studies. Samples were tested for strength properties based on standard ISO 527 for tensile strength at break, ISO 604 for compressive strength, ISO 178 for flexural strength, using a Kratos Universal Mechanical Testing Machine (Brazil). Charpy impact strength of both the matrix and the composites were determined. Tests were conducted as per ISO 179, while Vicat softening temperature was determined as per NBR 7139 : 81 and Shore D hardness as per ASTM D 2240 : 02.

Microscopy Studies. Morphology of the dried ground heart-of-peach palm sheath particles used in the study was obtained using an optical microscope (Make: Carl Zeiss). Then, the aspect ratio of the residues was calculated using Image J free software from National Institute of Standards and Technology (NIST).

Fractographic studies on the tensile tested samples were carried out using Shimadzu model SSX-550 scanning electron microscope. For this purpose, the fractured ends of the broken specimens were mounted on aluminum stubs and sputter-coated with a thin layer of gold. Some samples were also fractured in nitrogen temperature, sputter coated before observing them under the microscope.

RESULTS AND DISCUSSIONS

Specific Gravity

Figure 3 shows the variation of specific gravity of PP composite as a function of filler content. It can be seen that specific gravity of PP increases linearly with the filler content until 30% of

Figure 4. Photomicrograph showing morphology of heart-of-peach palm sheath waste residue. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

waste residue and thereafter decreases. An increase in the specific gravity of the composite over the neat PP has also been observed recently even in the case of nanocomposite.[18]

This could be due to (a) the lack of good mixing above 30% of filler and (b) possible existence of micro volumes not filled by the polymer matrix. Also, at this 30% concentration, maximum crystallinity was observed for the matrix in DSC analysis (Results and Discussions section). Also, the hardness, Vicat softening temperature, and flexural and compressive strength values increased reaching a maximum at 30% filler content. At this composition of fillers, nucleation effects are induced on the matrix with higher transcrystallinity and, consequently, improved shear transfer and adhesion filler/matrix interface as reported elsewhere.[2,3,18]

Morphology Studies

Figure 4 shows the dried waste residue. The average size of the particles is 0.1 mm with an aspect ratio ranging between 1.0 and 11.

Chemical Composition

Table 1 shows chemical assay of the oven dried waste residue used as filler in PP matrix in this study. It can be seen from the table that compared with chemical composition of wood of *Pinus taeda*, the lignin content is lower in this waste residue, while the cellulose, extractives, and ash contents are much higher than those of the wood mentioned.

X-ray Diffraction Studies

Figure 5 shows the diffractograms of the matrix PP, and the three composites studied in this investigation. As can be seen from the figure, the diffractograms are typical of semicrystalline isotactic PP polymers with α- and β-phases as observed earlier.[18] As a peak at 20.2° assigned to (117) crystallographic plane[28] is not observed, it may be assumed that the gamma phase is absent. It is also observed from the figure that there is slight displacement of the 2θ Bragg angle and peak height of α-phase to higher values with increasing content of waste residue up to 30%, probably due to the presence of both crystallographic α- and β-phases as observed in the case of PP containing β-nucleator.[18] On the other hand, peak height of β-phase decreased with increasing waste residue content from 20%. At this residue content, the diffraction peak was the highest at 16.7° for (040) plane assigned by Busse et al.,[29] which suggests a preferential orientation on PP polymer induced by the waste residue. This could be attributed to a columnar transcrystallization on filler particles surface with the lignocellulosic material used here as a β-phase nucleating agent on the PP polymer similar to those reported elsewhere.[2,3,18,28] Further, the decreasing peak intensity on diffractograms corroborates the DSC analysis (Thermal Studies section), which indicates a decreasing crystallinity index, although not linearly with filler content.

Table I. Chemical Composition and Heat Value of the Heart-of-Peach Palm Sheath

Properties of the heart-of-palm sheath residue	Content (%)
Humidity	7.0 (±0.18)
Klason lignin	22.0 (±0.40)
Cellulose	41.4 (±0.14)
Hemicellulose	23.3 (±0.36)
Extractives	7.4 (±0.11)
Ash	3.47 (±0.02)
High heat value (MJ/kg)	17.8 (±0.10)

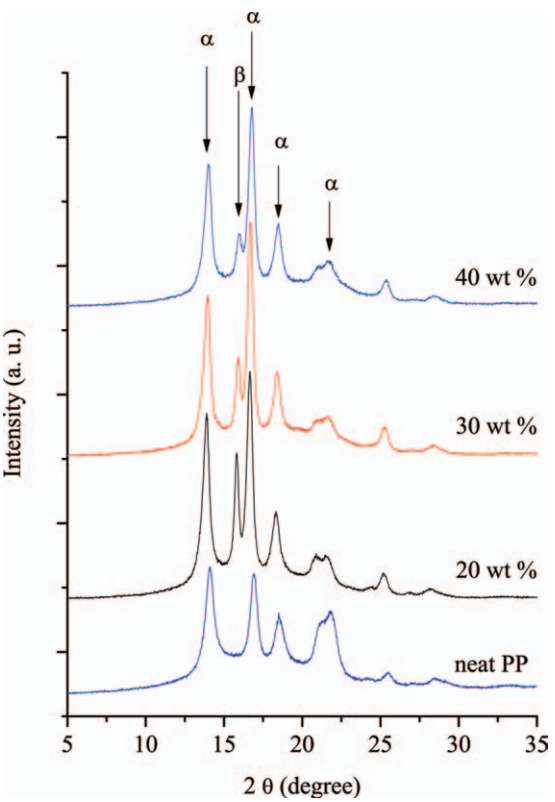

Figure 5. X-ray diffraction curves of neat PP and its composites with 20, 30, and 40 wt % of heart-of-peach palm sheath waste residue. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

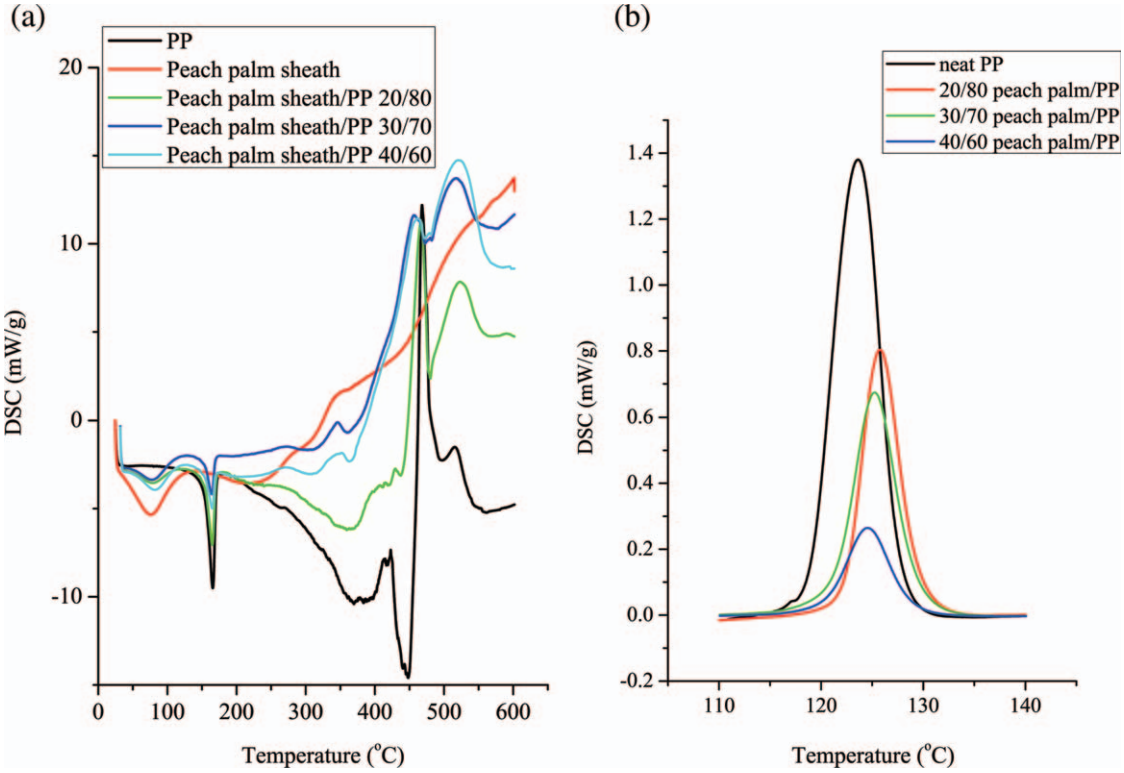

Figure 6. (a) DSC curves of neat PP, heart-of-peach palm sheath residue and their composites with compositions 20/80, 30/70, and 40/60 wt %. (b) DSC curves of neat PP and their composites with the compositions of 20/80, 30/70, and 40/60 wt % showing crystallization during cooling at 5°C/min from 180°C. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

Thermal Studies

Figure 6(a) shows thermograms (DSC curves) during heating (for melting and thermal degradation behavior) of neat PP, filler waste residue, and their composites, while Figure 6(b) shows the thermograms of neat PP and its composites with with filler/matrix compositions of 20/80, 30/70, and 40/60 wt % after keeping them at 200°C, whereby crystallization of these materials can be understood. Table 2 summarizes the results obtained from these curves, that is, crystallization temperature (T_c), melting point (T_m), degree of crystallization or crystallanity (X_c), and the heat of crystallization (ΔH_f). The degree of crystallization of PP was calculated using the following relationship earlier used by Prachum et al.[18] and Amash and Zugenmaier[2,3]:

$$X_c(\%\text{crystallinity}) = (\Delta H_f/\Delta H_f^0) \times (100/w) \qquad (1)$$

where, ΔH_f is the heat of crystallization, w is the mass fraction of PP in the composite and a value of ΔH_f^0 =190 J/g was taken for 100% crystalline isotactic PP, similar to the value used earlier by other researchers.[2,3]

It can also be seen from Figure 6(a) that the melting point of the neat PP is 165.7°C, while there is no thermal event around this temperature for the filler. From Table 2, it is also evident that there is hardly any significant change in the melting point of the composite with the addition of waste residue, thus suggesting that the addition of this lignocellulosic material causes only a marginal effect on the melting point of the PP matrix as reported for cellulose- and xylan-filled PP composites.[2,3] Similarly, from the Figure 6(b) and Table 2, it can also be seen that the crystallization temperature is shifted to higher temperatures by approximately 1–2°C with the addition of heart-of-peach palm sheath; however, crystallization temperature decreased with increasing amount of heart-of-peach palm sheath. Such shift in the crystallization temperature is reported for other lignocellulosic materials[2,3,30] and also in β-nucleated PP-montmorillonite nanocomposites indicating the waste residue acts as a β-nucleating agent.[18,31]

Furthermore, as can be seen from Table 2, the crystallization index (X_c) and heat of crystallization (ΔH_f) decrease with the addition of peach palm sheath. Nevertheless, the crystallization index of PP matrix increases with the addition of cellulose fibers, similar to the observations reported earlier[2,3] including

Table II. Thermal Properties of Neat PP and Heart-of-Peach Palm Sheath/PP Composites

Sample	T_c	T_m	ΔH_f (J/g)	X_c
PP	123.6	165.7	93.4	49.2
20/80 peach palm/PP	125.8	164.8	46.4	30.5
30/70 peach palm/PP	125.3	164.2	46.2	34.8
40/60 peach palm/PP	124.5	165.1	18.1	15.9

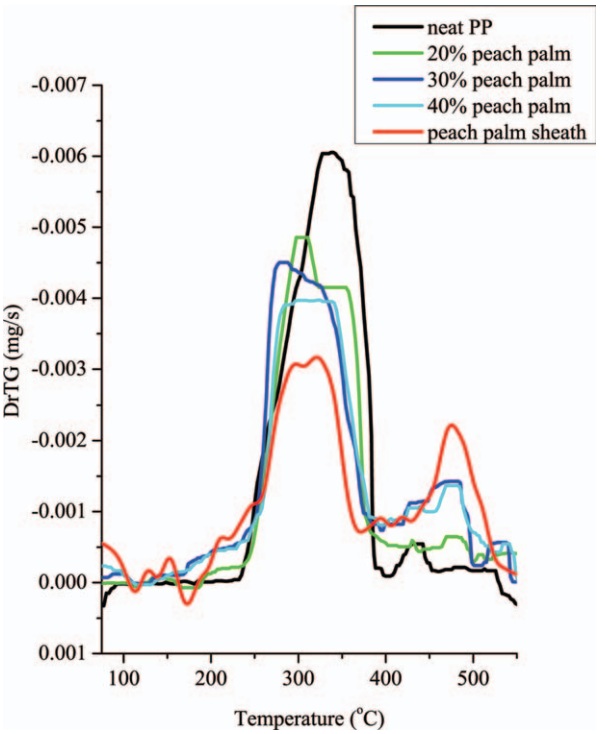

Figure 7. DTG thermograms for heart-of-peach palm sheath residue, neat PP, and their composites with the compositions of 20/80, 30/70, and 40/60 wt %, respectively. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

PP-nanocomposites.[18] However, value of the X_c reaches a maximum for composites when the filler content is around 30 wt %. Also, the ΔH_f practically did not vary in the range 20–30 wt %, although ΔH_f value was expected to decrease linearly with filler content,[3] which did not happen. This could be due to the filler acting as a nondiluent in the matrix and has not so good adhesion with the matrix, while it is contrary when a decrease is observed.[3]

On the other hand, Figure 7 shows the derived thermogravimetry plots for neat PP, filler heart-of-peach palm sheath waste, and their composites. These indicate the rate of mass loss and the maximum mass loss during heating of these materials.

It can also be seen that the incorporation of lignocellulosic material (waste residue) into PP leads to early thermal degradation. The figure also shows that there is a loss of weight at lower temperatures for all composites studied in this investigation compared with the matrix PP, thus suggesting that the addition of peach palm sheath waste decreases the overall thermal stability of the material. This could be explained as below:

In general, thermal stability of lignocellulosic fibers incorporated polymer composites depends on the chemical composition and thermal stability of the former and the bonding between the fiber and the matrix. For example, in many lignocellulosic fibers, mass loss between 200 and 260°C is associated with the degradation of hemicelluloses, whereas those in the range of 240–350°C and 280–500°C are related to the decomposition of cellulose and lignin, respectively.[32] In addition, the polymer used also decomposes at higher temperatures and part of the weight loss of the composite will be due to its contribution also. In general, improved thermal stability is obtained when good adhesion exists between the fiber and the matrix,[33,34] which reduces the mass loss in the sample. In that case, when the fiber acts as filler (no good adhesion with the matrix), it

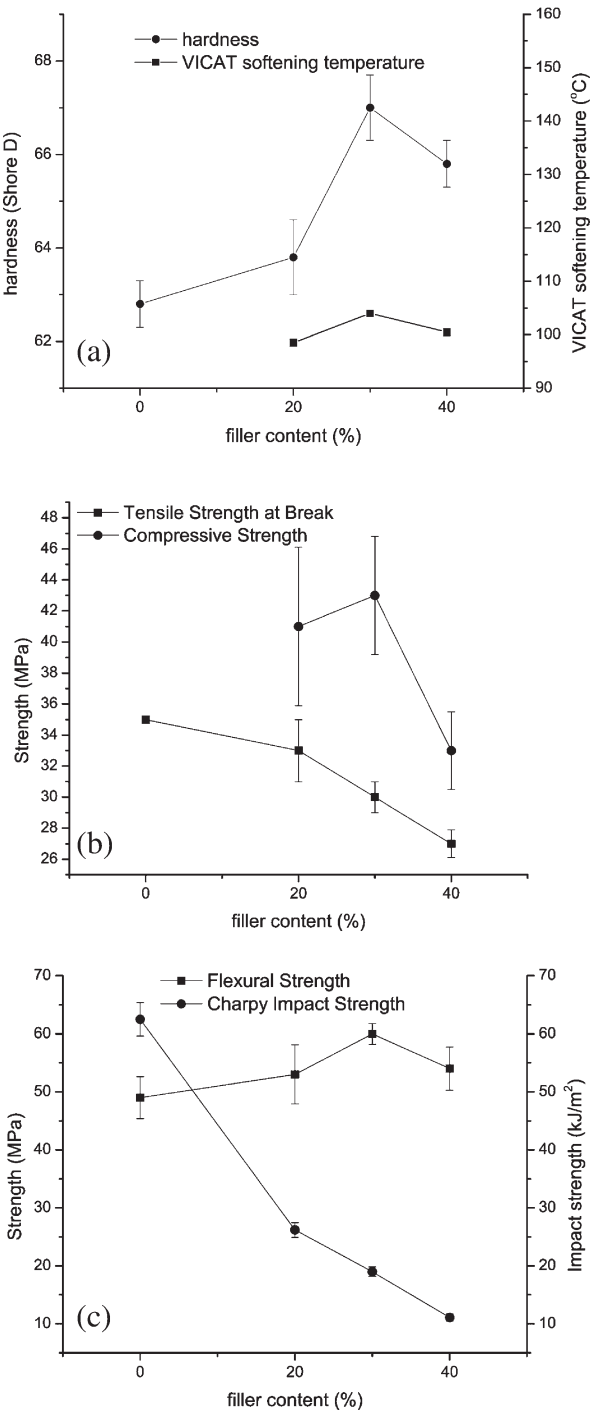

Figure 8. Plots of (a) vicat softening temperature and Shore D hardness, (b) tensile and compressive strengths, and (c) flexural and Charpy impact strengths as a function of filler (heart-of-peach palm sheath waste residue) content.

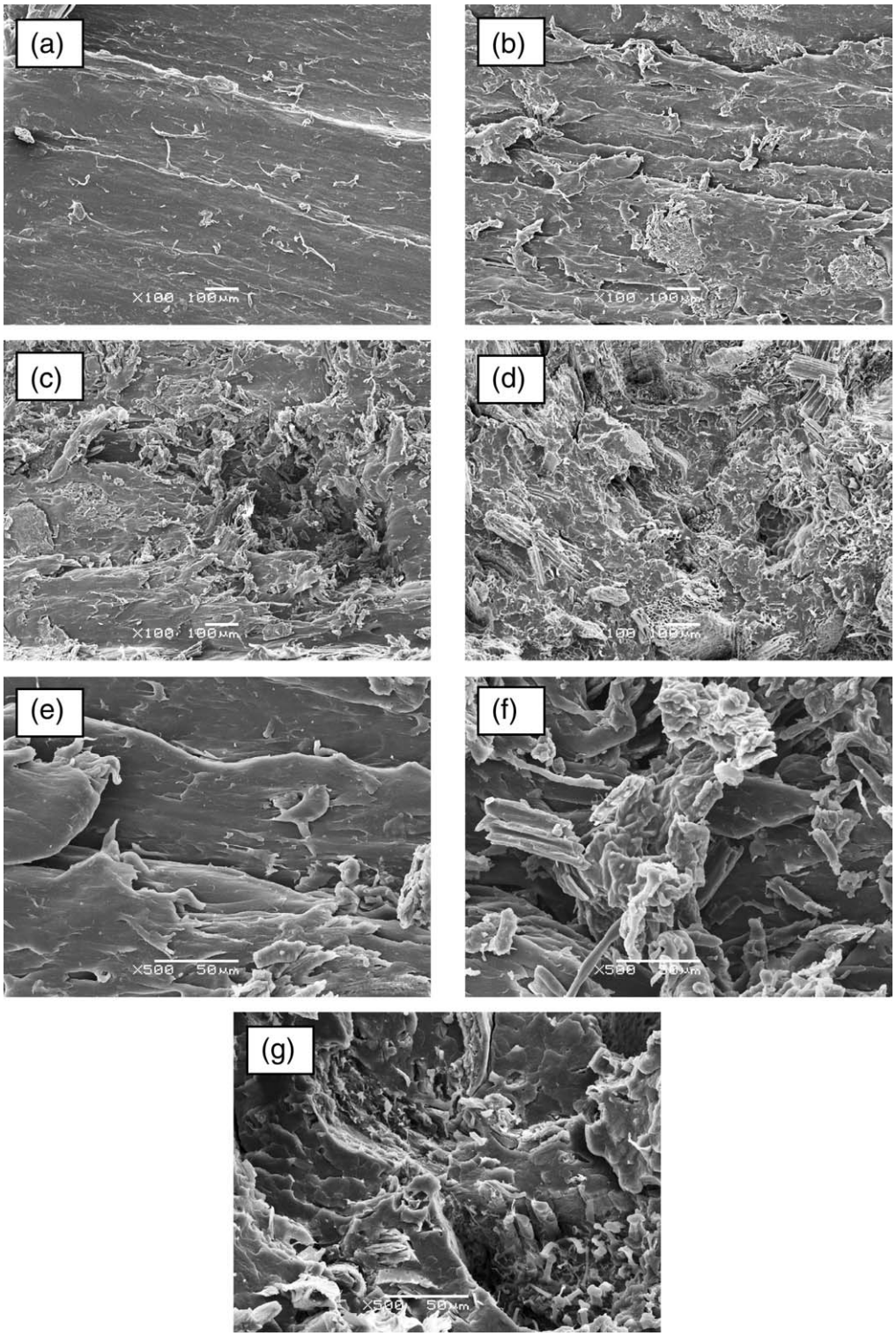

Figure 9. Fractographs of (a) neat PP (matrix); composites of PP with different amounts of heart-of-peach palm sheath chips (b) PP: 20 wt %; (c) PP: 30 wt %; (d) PP: 40 wt % (all at ×100); (e) PP: 20 wt %; (f) PP: 30 wt %; and (g) PP: 40 wt % (all at ×500).

may act only as a partial β-nucleating agent of PP and thus decreasing the crystallization and melting temperatures,[18] which also determine thermal stability. On the other hand, lower thermal stability of composites is observed when the lignin favored a better interaction between the fibers and the polyester matrix, whose polarity is not compatible with that of cellulose.[35]

It should be noted that for composite production, the lignocellulosic materials should be dried and this leads to intense

energy consumption. However, this can be overcome using part of the residue to generate necessary heat for the drying of this material considering the high level of humidity in them, as oven drying of this material would lead to cost and thus impede the industrial applications for this material. In fact, the waste residue is found to have high heat value of 17.8 MJ/kg (determined by the authors) supporting this possibility.

Mechanical Properties

Figure 8(a) shows the plots of Shore hardness and Vicat softening temperature; Figure 8(b) shows tensile and compressive strengths; and Figure 8(c) shows flexural and Charpy impact strengths as the functions of filler content, respectively. It can be seen from the figures that the hardness, Vikat softening temperature, flexural and compressive strength values increase reaching a maximum at 30% filler content and these values decrease for 40 wt % filler. For example, hardness increased from 63 Shore D for neat PP to 67 Shore D for 30% waste residue content, which decreased with further filler content. Similarly, the softening point also increased from 100°C for 20% waste residue composite to 105°C for 30% waste residue composite and compressive strength also followed similar trend (40 MPa for 20% waste residue to 42 MPa for 30% waste residue). On the other hand, flexural strength increased slowly from 50 MPa for the neat PP to 52 MPa for 20% waste residue content and then steep increase to 60 MPa at 30%, where after it decreased. Further, the tensile strength at break and the Charpy impact strength values continuously decreases with increasing waste residue content. For example, tensile strength decreased continuously from 35 MPa for neat PP to 32 MPa, 30MPa and finally to 27 MPa for 20, 30, and 40% waste residue, respectively. Similarly, impact strength decreased initially sharp from 62 MPa for neat PP to $\sim$ 27 MP for the incorporation of 20% waste residue and further steadily continuous up to 10% waste residue content. Increases in hardness and flexural strengths with increasing amount of filler are expected due to the nature of the filler over that of the matrix. Similarly, the Vicat softeningtemperature increases slowly up to 20 wt % filler and presents a steep increase at 30% filler content that may also due to the nature of the filler over that of the matrix. In the case of compressive strength, although it increases with increasing filler content, its decrease is more pronounced after 30% filler incorporation. This is understandable as it is well known that this property is more sensitive to voids present in bulk of the composite, which suggests that the composites with higher filler content (40 wt %) may contain the voids as well as the agglomeration of filler as mentioned earlier (Morphology Studies section). Thus, it may be concluded that with the exceptions of Charpy impact and tensile strengths, all other evaluated properties can reach their maximum values with the addition of $\sim$ 30% w/w of heart-of-peach palm sheath waste residue into the polymer.

Continuous decrease of Charpy impact strength with increasing filler content may be attributed to the minimized deformation of the PP matrix with increasing filler content. Thus, less energy would be absorbed by the composite, which would behave more brittle than the PP matrix. In addition, presence of filler particle provides points of stress concentrations with consequent sites for crack initiation. In fact, steep decrease in impact strength with increasing nucleating agent from 0.1 to 0.2 wt % and then steady decrease for further addition of the filler content was observed in injection molded PP containing β-nucleating agent composite, which was attributed to the influence of the nucleating agent.[31]

Observed decrease in tensile strength with the incorporation of the heart-of-peach palm sheath waste may probably be due to the lack of proper adhesion between filler and the PP matrix as seen in the fractographs (See Fractographic Studies section for details). This is a common phenomena observed in other composites[6,32] as the irregular shape of fillers do not support stresses transferred from the polymer matrix. In such cases, the incorporated material would act mostly as filler rather than the reinforcement.

Fractographic Studies

Figure 9(a–d) show fractographs of tensile tested neat PP (matrix) and its composites with 20, 30, and 40 wt % of filler (heart-of-peach palm sheath waste) at lower magnifications, while Figure 9(e–g) show the same at higher magnifications for 30 and 40% of filler content composites. It can be seen that the fracture surface of the neat PP is typical of polymer fracture surface (ductile) with almost smooth and flat surface, while those of the composites reveal rough surfaces, the roughness increasing with the increasing filler content. This suggests that the resistance to crack growth in the matrix is markedly different with different amounts of waste residue as observed earlier in the case of β-nucleated PP composites.[16]

Some voids as well as agglomeration of fillers at higher filler content with no trace of fiber pullouts in these figures were observed suggesting the existence of some adhesion between the filler and the matrix, which may not be sufficient to impart increase in tensile strength. This is also understandable as due to the low aspect ratio of the waste residue used, as higher aspect ratio fillers not only favor β-phase nucleation but also the reinforcing effect of the matrix.[17] In addition, to achieve higher strength, filler distribution should be uniform with very good adhesion, all of which seemed to be absent in the present case. This is supported by the observation of the presence of some broken fibers as shown in Figure 10 with some fiber pull outs in the manually fractured surfaces of the composites under liquid nitrogen environment. However, better adhesion between the filler and the matrix may be possible using a high shear twin-screw extruder, coupling agent, and sheath of heart-of-palm fibers with higher aspect ratio (which favors the occurrence of β-form of PP[18]), all of which may lead to the reinforcement effect in PP.

As a final remark, this study has indicated that although it is possible to incorporate a maximum of 40% w/w of heart-of-peach palm sheath waste into PP using a single screw extruder, 30% incorporation could be optimum as observed from the maximum properties at this amount of filler content as observed by others.[18] Also, increasing amount of filler increases the viscosity of the polymer matrix, impeding good dispersion of fibers with addition of more filler, which may also be the reason for decreasing tensile strength. However, above results on compressive strength of the PP containing heart peach palm sheath waste composites suggest that these composites may offer good prospective for the application of this new composite in

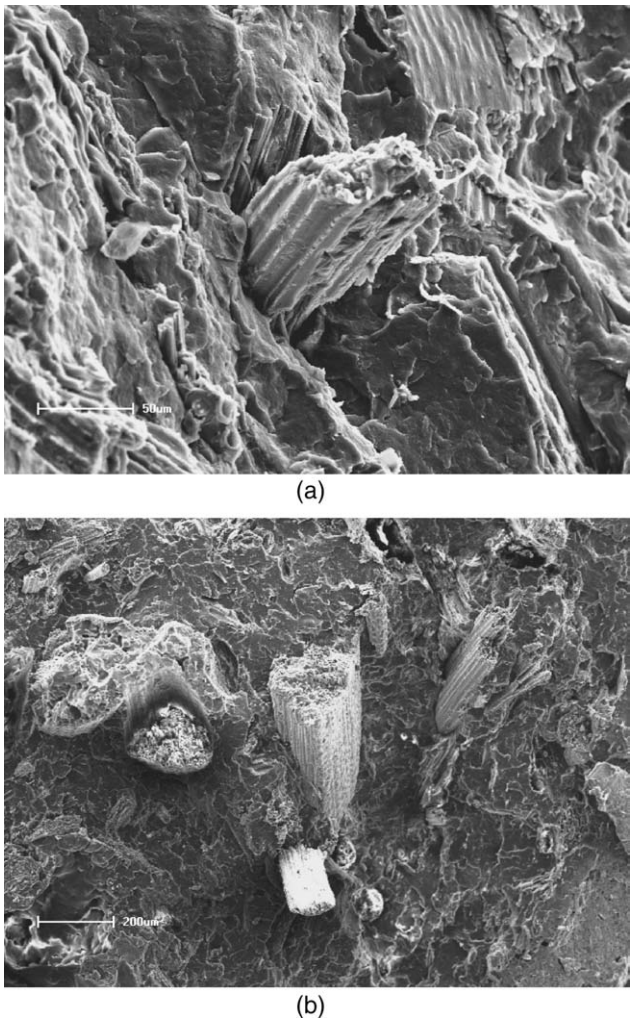

Figure 10. Fractographs of composites of PP with different amounts of heart-of-peach palm sheath waste residue (a) PP: 30 wt % (×300); (b) PP: 40 wt % (×60).

furniture, decoration, and construction items such as frames, sidings, decks, and fences. Therefore, the peach-palm composite is a viable and interesting alternative for industrial application in place of nonrenewable wood as well as the expensive synthetic fiber incorporated polymer composites.

Furthermore, it is well known fact that thermal stability affects physical and chemical properties, which in turn affect the mechanical properties of any material in particular lignocellulosic fiber-polymer composites. For example, as mentioned above, in many lignocellulosic fibers, mass loss between 200 and 260°C is associated with the degradation of hemicelluloses, whereas those in the range of 240–350°C and 280–500°C are related to the decomposition of cellulose and lignin, respectively. In addition, the polymer used also decomposes at higher temperatures and part of the weight loss of the composite will be due to its contribution also. Thus, at higher temperatures, chemical constituents, which also dictate the physical and mechanical properties of these materials, show deterioration and hence affect the final properties of the product (in this case composites). Hence, the performance of the product is affected at high temperatures, and therefore, such materials cannot be used in such applications, which involve rubbing, as this would increase the temperature of the product. Thus, applications such as packaging could be proper for these materials.

CONCLUSION

Heart-of-peach palm sheath, which is a waste from the industry, is successfully used as filler up to 40 wt % in PP to prepare composites.

Values of specific gravity, Vicat softening temperature, Shore D hardness, and compressive and flexural strengths increased with the addition of palm peach sheath chips reaching maximum values at 30% w/w its content. This result coincides with the observed maximum crystallinity of the composite. Moreover, the filler induces transcrystallization on the PP polymer.

On the other hand, values of tensile strength at break and Charpy impact strength continuously decreased with filler loading, as usually observed for lignocellulosic–thermoplastic composites.

Thermal stability of the composite decreased compared with that of PP matrix. The above observed results indicate PP-heart-of-peach palm sheath composites could be potential candidate in many conventional applications to substitute wood and composites based on synthetic fiber polymer composites.

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